A peer-reviewed version of this preprint was published in PeerJ on 11 January 2016.

View the peer-reviewed version (peerj.com/articles/1559), which is the preferred citable publication unless you specifically need to cite this preprint.

Wasowicz P. 2016. Non-native species in the vascular flora of highlands and mountains of Iceland. PeerJ 4:e1559
https://doi.org/10.7717/peerj.1559

Non-native species in the vascular flora of highlands and mountains of Iceland

Pawel Wasowicz

Icelandic Institute of Natural History, Borgir vid Nordurslod, P.O. Box 180, 602 Akureyri, Iceland, pawasowicz@gmail.com, pawel@ni.is

Abstract

The highlands and mountains of Iceland (defined here as areas located above 400 m a.s.l) are one of the largest remaining wilderness areas in Europe. The present study provides the first comprehensive and up-to-date data on non-native plant species from these wilderness areas. Overall, 16 non-native vascular plant specieswere detected, including 11 casuals and 5 naturalised taxa (1 invasive). Results showed that the central highlands are most vulnerable to non-native plant colonisation, while other mountain and highland areas in Iceland seem to be far less impacted by non-native plants. Clear hotspots of alien flora are evident, especially in popular tourist areas in the highlands and mountains such as hot springs, geothermal areas, mountain huts and shelters, as well as main roads and tracks. Temporal trends characterizing non-native plant colonization show that the process is still in its initial phase. This research suggests that human-mediated dispersal is the main driving force increasing the risk of invasion in Icelandic highlands and mountain areas.

Key words

alien flora, Iceland, highland, mountain flora, invasive species, tourism

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Introduction

There are conflicting views on the question whether the Arctic should be considered a pristine, virgin environment or whether it has been changed and influenced by human activities (Elven et al. 2011). It seems that if vascular plants are taken into account, the former point of view is more appropriate. Overall, there is no known evidence of human mediated extinction of any Arctic vascular plant species, the total number of naturalised alien plant species is low or negligible in most of the Arctic's phytogeographic regions, and the natural "phytogeographic" pattern is intact in the Arctic (Elven et al. 2011). However, this is not the case in the North Atlantic region of the Arctic that encompasses Greenland and Iceland, where human settlements date back to Medieval times (McGovern 1990). In this region the number of non-native plants is much higher, especially in areas with a long history of human activity (e.g. Wasowicz et al. 2013).

The highlands and mountains of Iceland (defined here as areas located above 400 m a.s.l), which account for ca. 40% of the country, are some of the most pristine environments of Europe due to their remoteness and harsh climate (Einarsson 1994). The central highlands are considered the largest territories in Europe south of the Arctic Circle that have never been permanently settled by humans (Vésteinsson 1998). Since the retreat of the ice sheet from the last ice age, undisturbed processes of ecological succession have created a variety of unique, natural plant communities that have been found to be one of the key factors in maintaining natural plant distribution patterns in Iceland (Wasowicz et al. 2014). It seems, however, that the combination of increasing anthropogenic pressure and climate change may contribute to significant changes in these fragile ecosystems (Wasowicz et al. 2013).

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Non-native plant species are one of the main threats to the unique biodiversity in the Icelandic highlands. Alien plant species can significantly impact species richness, survival and productivity of native communities (Gaertner et al. 2009, Pysek et al. 2012a). Furthermore, non-native plant colonization is far more likely to negatively impact native plant and animal richness on islands than on the mainland (Pysek et al. 2012a). Climate change is another risk factor that may seriously affect the flora in the Icelandic highlands by deteriorating habitat conditions for native, cold adapted species (Lassuy and Lewis 2013, Wasowicz 2013) and favouring the spread of alien species, leading to new invasions and range expansion of already naturalised alien taxa (Thuiller et al., 2007).

Given these threats to the Icelandic highlands and mountains, the present study aimed to evaluate the impact of non-native plant taxa on the vascular flora of these areas . The objectives of the study were to:

(1) generate a checklist of alien plant species present in the Icelandic highlands and mountains

(2) assess their naturalisation status

(3) define spatial patterns and hotspots of their distribution

(4) analyse temporal trends in the data.

Materials and methods

Definitions used

The study focused on non-native plant species as defined by Pysek et al. (2004), which represent taxa whose presence in a given area is due to intentional or unintentional human involvement or which have arrived there without human intervention from an area where they are alien. Non-native species are further subdivided into two categories: casual and naturalised

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

species. Casual species were defined as alien plants that may flourish and even reproduce occasionally outside cultivation in an area, but that eventually die out because they do not form self-sustaining populations, and rely on repeated introductions for their persistence. Naturalised species on the other hand, were defined as alien plants with self-sustaining populations for at least 10 years without direct human intervention (or in spite of human intervention), but rather by recruitment from seed or ramets (tillers, tubers, bulbs, fragments, etc.). Invasive alien species were included under naturalised taxa, and followed Pysek et al.'s (2012 b) definition.

Data origin

Data were obtained from the Icelandic Institute of Natural History. The institute has the largest repository of biodiversity data in Iceland, containing over 500,000 georeferenced records of plant species distribution. Only records of non-native taxa (Wasowicz et al. 2013) were considered for the study. Overall, 9,396 records collected between 1840 and 2014 were examined, including vouchered specimens deposited in AMNH and ICEL herbaria, field observations and literature data records.

Spatial analyses

All georeferenced data from the database were converted into shapefiles using QGIS software. Elevation data were retrieved from digital elevation model of Iceland (20 m per pixel) downloaded from http://gatt.lmi.is . Elevation in meters was then assigned to each data point using point sampling tool in QGIS. A database was developed that contained georeferenced species occurrences and elevation data. This database was queried to identify records with an altitude of ≥ 400 m a.s.l. (130 in total; see supplementary materiall).. In order to identify areas with high concentration of non-native species records, a heat map was generated in QGIS using a radius of 5.000 m.

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Checklist, temporal trends

A checklist of non-native taxa was developed, summarizing information on taxonomy, time of residence, naturalisation status, biogeographical affinities and a life form (Raunkiær, 1934). Native distribution of alien taxa was recorded at a continent scale. If the taxa were present in two continents, they were included in both totals.

The year of first observation for each species record was retrieved from the database and cumulative number of species introduced and number of observations were plotted against time. Curves were plotted in SigmaPlot using locally weighted regression - LOESS (Cleveland 1979), using a sampling proportion of 0.1 and polynomial degree set to 1.

Results

Overall, 16 non-native plant taxa were recorded in the Icelandic highlands and mountain areas between 1840 and 2014 (Table 1). According to the criteria proposed by Pysek et al (2004), 11 taxa (69% of total non-native flora) were classified as casual aliens, while 5 taxa (31% of non-native flora) were classified as naturalised. Based on the criteria by Pysek et al. (2012b), only *Lupinus nootkatensis* can be classified as an invasive plant.

All non-native vascular plants in the Icelandic highlands and mountain areas belong to 11 families and 16 genera. Only two families were represented by more than one genus: *Poaceae* with 5 genera, and *Boraginaceae* with 2 genera. Hemicryptophytes were the most common non-native plants (10 taxa, 62% of total non-native flora), while therophytes were far less common (2 taxa, 12%). Geophytes , nano-phanerophytes and phanerophytes only had one taxon each (6%) (Table 1).

Evaluation of the geographic origin of non-native taxa showed that 10 taxa were included in the European group of origin, 9 taxa in the Asian group and 6 taxa in the Northern

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

American group (Table 1). Analysis of the geographic distribution of non-native taxa records indicate that they are concentrated mainly within the central highlands (Fig. 1). A closer examination of the pattern of occurrence within the central highlands, revealed that hotspots of non-native plants coincided with disturbed areas related to man made objects such as huts, shelters and roads. In addition, the highland areas around Myvatn Lake were also a hotspot for non-native species. Highland and mountain areas outside the central highlands appeared to be less colonised by non-native plants. For example, the highlands in the Western Fjords (NW Iceland) and in the eastern part of the country seemed to have the fewest non-native plant taxa. The results showed clearly that naturalised species are a lot more frequent and widely distributed than casual aliens (Fig. 2 b,c)

The cumulative number of first taxa records was plotted against time to examine temporal trends in alien taxa immigration to the highlands and mountain areas. The analysis showed that the trend recorded for the highlands and mountain areas is very similar to the overall trend of non-native species immigration to Iceland (Fig. 2a). It seems, however, that a steady, linear increase in the number of non-native taxa records started much later in highlands than in Iceland as a whole (Fig 2a). The same pattern is clearly visible when the number of observations of non-native plant taxa is taken into account (Fig.2 b). A clear growth trend is seen in the highlands a few decades after it started in the lowlands or Iceland as a whole. The curve for the highland areas seems to be a lot steeper than the curve plotted for the entire country (Fig. 2b).

Discussion

Over 300 non-native plant taxa have been recorded in Iceland so far (Wasowicz et al. 2013, Wasowicz 2014). The results of the study indicate that only a very small percentage of these alien species is able to reach the highlands and mountain areas. Currently, 95% of non-

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

native taxa recorded in Iceland has yet to be found in the highlands and mountain areas. This suggests that there are still strong environmental factors preventing unlimited spread of non-native plants from lowland areas to the highlands.

Climate is one potential factor that explains the low rate of colonization success among non-native plants in the highlands. With very few exceptions, most of the highlands and mountain areas in Iceland have a mean temperature in July less than 10^{o}C (Einarsson 1984), and thus can be treated as Arctic areas based on climatic criteria (Przybylak 2002). These unfavorable conditions with low temperature and very short vegetation period restricts the growth of many species in the Icelandic highlands and mountain areas, including non-native taxa (Wasowicz et al. 2013). Research on the biogeographical patterns of the native Icelandic flora has also shown that climatic factors are crucial in shaping the geographic distribution of native flora (Wasowicz et al. 2014).

It is well known that non-native species richness increases with the level of urbanisation and is positively correlated with human population density (McKinney 2001, Holway 2005). From the beginning of the settlement, farms and and other centres of human activity in Iceland were located almost exclusively within lowland areas, especially in flooded wetlands (Vésteinsson 1998), where climatic conditions were good enough for agriculture. This pattern of settlement in turn, limited the economic significance of the highlands and mountain areas that were used almost exclusively for sheep grazing until the mid-1960 (Sæþórsdóttir and Saarinen 2015). Low rate of human settlement and visitation and almost negligible economic use of these areas, contributed to extremely small propagule pressure thus limiting the spread of non-native plant taxa in the past.

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

The results suggest that only taxa previously naturalised within lowland areas are able to effectively colonise the highlands. All taxa naturalised in highlands and mountain areas have been recorded as naturalised in the lowlands (Wasowicz et al. 2013). Furthermore, most of the casual taxa in the highlands are naturalised in the lowlands (Wasowicz et al. 2013). This shows that colonization of highland environments in Iceland is a "second step" in the process of naturalisation of the species within the country. There is no evidence available so far showing a different direction of naturalisation process (i.e. a species naturalised in highlands and spreading down into lowlands).

Comparison of the geographic origin of non-native plant taxa showed that most have an European origin, constituting 66% of all non-native flora in the highlands, and 49.2% of all non-native plants in Iceland (Wasowicz et al. 2013). Also taxa of Asian and Northern American origin scored high in both in the highlands and the country as a whole. In the highlands, non-native plants from Asia accounted for 55% all alien flora, while 33% of them were from North America. The percentage of non-native plants from North America in the Icelandic highlands is significantly greater than that seen for the entire country (8.9%, Wasowicz et al. 2013).. This is due to the fact that several non-native species from Northern America have been deliberately introduced into the highlands, becoming naturalised at a faster rate than other non-native species. Plants such as *Lupinus nootkatensis*, *Deschampsia caespitosa* subsp. *beringensis* and *Salix alaxensis* are good examples of this. Given the high level of environmental matching between their native range and the Icelandic highland areas, these species are most likely to spread quickly and effectively in the highlands. Currently, Alaska lupine (*L. nootkatensis*) is the most widespread and invasive non-native plant in the Icelandic highlands.

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Most non-native plants are found in the central highlands. Also, fairly accessible highland areas close to Myvatn Lake (North-Eastern Iceland) have been influenced by naturalised alien plant species. The climatic conditions in the north-eastern part of the country allowed human settlement and farming activities above 400 m a.s.l, facilitating the introduction of non-native plants. In contrats, areas located above 400 m a.s.l. in other parts of Iceland (e.g. the Western Fjords and Eastern Fjords) appear to be almost free of non-native plant species. This pattern of spatial occurrence can be explained by human-mediated dispersal. A closer examination of places with very high numbers of non-native species shows that they are mostly found in areas with tourist attractions such as hot springs (e.g. Hveravellir, Laugafell) and areas with geothermal activity (e.g. Reykjahlíð, Námafjall and Krafla volcano), as well as near hiking huts and shelters along the highlands (e.g. Jökullheimar). The road network into the highlands is another source of propagules and is very likely facilitating the spread of non-native plants into these areas. The study seems to confirm that human-mediated dispersal along a road network is one of the most important factors contributing to plant dispersal (von der Lippe et al. 2013).

Temporal trends characterising non-native plant colonization show clearly that the process is still in its initial phase. Relatively low number of non-native plant species was recorded in the highland areas when compared to the rich alien flora in the lowlands (Wasowicz et al. 2013). This suggests that further colonisation may occur, especially if climatic constraints are significantly reduced or even removed by climate change, which has been suggested by recent modelling experiments (Wasowicz et al. 2013). A sharp increase in the number of species observations after 1960, may be indicative that construction of the first large hydropower plants in the central highlands in the mid-1960s contributed to an increase alien plant colonisation. The construction of these hydropower plants involved significant improvements in road

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

infrastructure, making some areas more accessible including Landmannalaugar (Sæþórsdóttir and Saarinen 2015).

In recent years Arctic wilderness environments have become a major tourist attraction, and the central highlands in Iceland are considered one of the largest remaining wilderness areas in Europe (Sæþórsdóttir and Saarinen 2015). The increase in international visitors coming to Iceland is particularly high, where the number of tourists has grown from 72,600 in 1982 to ca. 1 million in 2014 (Sæþórsdóttir and Saarinen 2015). It is estimated that about one third of tourists visit the central highlands (Icelandic Tourist Board 2012). These values suggest that the influx of propagules carried on the clothing, gear and vehicles of visitors to the central highland is likely higher than ever before and will probably continue to grow with increasing tourism. Recent studies in Antarctica and the Arctic have shown that this type of plant propagule transfer should be considered as very important source of propagules of non-native species (Whinam et al. 2005, Lee and Chown 2009, Ware et al. 2011, Chown et al. 2012, Huiskes et al. 2014). The increased transfer of propagules poses a great danger to the unique and fragile environments in the highlands and mountain areas of Iceland. Moreover, this increased propagule pressure will likely contribute to more secondary invasions of existing non-native species through facilitated seed transport along road networks (von der Lippe et al. 2013), as well as through the arrival of new alien species brought by tourists from lowland areas and abroad. An example of this is *Digitaria ischaemum* (*Poaceae*), which seems to be have spread between thermal areas in southern Iceland via the hiking shoes of visitors. Future actions to facilitate travel through the central highlands (e.g. construction of new road tracks or improvement of existing routes), will inevitably increase the number of visitors, leading to a greater inflow of seeds and other plant propagules of non-native taxa and a higher risk of invasion.

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Conclusions

The present research shows that non-native plant species are one of the major threats to preserving pristine environments in the highlands and mountain areas of Iceland. The presence of 16 non-native plants was evidenced, of which almost 30% are already naturalised in the highlands and mountain areas. Some of those species (L*upinus nootkatensis*, *Deschampsia caespitosa* subsp. *beringensis* and *Salix alaxensis)* can be considered as invasive (*L. nootkatensis*) or potentially invasive given their environmental matching between their native and novel environments. The central highlands are a hotspot of increased colonisation by non-native plant species, and human-mediated dispersal seems to be a major force contributing to the risk of invasion.

References

Chown SL, Huiskes AH, Gremmen NJ., Lee JE, Terauds A, Crosbie K, et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc Natl Acad Sci U S A 109: 4938-4943. doi: 10.1073/pnas.1119787109

Cleveland WS (1979) Robust locally weighted regression and smoothing scatterplots. J Amer Statist Assn 74: 829-836.

Einarsson MA (1984) Climate of Iceland. World survey of climatology 15: 673-697.

Elven R, Murray DF, Razzhivin V, Yurtsev BA (2011) Checklist of the panarctic flora (PAF). CAFF/University of Oslo, Oslo.

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Gaertner M, Den Breeyen A, Hui C, Richardson DM (2009) Impacts of alien plant invasions on species richness in Mediterranean-type ecosystems: a meta-analysis. Prog Phys Geogr 33: 319–338. doi: 10.1177/0309133309341607

Holway DA (2005) Edge effects of an invasive species across a natural ecological boundary. Biol Conserv 121: 561-567. doi:10.1016/j.biocon.2004.06.005

Huiskes AH, Gremmen NJ, Bergstrom DM, Frenot Y, Hughes KA et al. (2014) Aliens in Antarctica: Assessing transfer of plant propagules by human visitors to reduce invasion risk. Biol Conserv 171: 278-284. doi:10.1016/j.biocon.2014.01.038

Icelandic Tourist Board (2014) Heildarfjöldi erlendra gesta 1949–2014 [The total number of foreign guests 1949–2014]. Reykjavík:Icelandic Tourist Board.

Lassuy DR, Lewis PN (2013) Invasive species: human-induced. In: Meltofte H. (ed.) Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity. Conservation of Arctic Flora and Fauna, Akureyri, pp 558-565

Lee JE, Chown SL (2009) Breaching the dispersal barrier to invasion: quantification and management. Ecol Appl 19: 1944-1959. doi:10.1890/08-2157.1

McGovern TH (1990) The archaeology of the Norse North Atlantic. Annu Rev Anthropol 19, 331-351.

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

McKinney ML (2001) Effects of human population, area, and time on non-native plant and fish diversity in the United States. Biol Conserv 100: 243-252. doi:10.1016/S0006-3207(01)00027-1

Przybylak R (2002) Variability of air temperature and atmospheric precipitation in the Arctic. Springer Science & Business Media.

Pysek P, Richardson DM, Rejmanek M, Webster GL, Williamson M, Kirschner J. (2004) Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon 53, 131-143.

Pysek P, Jarosik V, Hulme PE, Pergl J, Hejda M, Schaffner U, Vila M (2012a) A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Glob Chang Biol 18: 1725–1737. doi: 10.1111/j.1365-2486.2011.02636.x

Pysek P, Danihelka J, Sadlo J, Chrtek J, Chytrý M, Jarosik V et al. (2012b) Catalogue of alien plants of the Czech Republic: checklist update, taxonomic diversity and invasion patterns. Preslia 84: 155-255.

Raunkiær C (1934) *The life forms of plants and statistical plant geography*. Clarendon Press.

Sæþórsdóttir AD, Saarinen J (2015) Challenges due to changing ideas of natural resources: tourism and power plant development in the Icelandic wilderness. Polar Rec (Gr Brit) doi:10.1017/S0032247415000273

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Vésteinsson O (1998) Patterns of settlement in Iceland: a study in prehistory. Saga book - Viking Society for Northern Research 25: 1-29.

von der Lippe M, Bullock JM, Kowarik I, Knopp T, Wichmann M (2013) Human-mediated dispersal of seeds by the airflow of vehicles. *PLOS ONE* *8*: e52733. doi: 10.1371/journal.pone.0052733

Ware C, Bergstrom DM, Müller E, Alsos IG (2012) Humans introduce viable seeds to the Arctic on footwear. Biological invasions 14: 567-577. doi: 10.1007/s10530-011-0098-4

Wasowicz P 2014. Identifying and ascribing the relative significance of introduction pathways for non-native plants into Iceland. Environ Soc-Econ Studies 2: 28-37.

Wasowicz P, Pasierbiński A, Przedpelska-Wasowicz EM, Kristinsson H (2014) Distribution Patterns in the Native Vascular Flora of Iceland. *PLOS ONE* 9: e102916. doi: 10.1371/journal.pone.0102916

Wasowicz P, Przedpelska-Wasowicz EM, Kristinsson H (2013) Alien vascular plants in Iceland: Diversity, spatial patterns, temporal trends, and the impact of climate change. Flora 208: 648-673. doi:10.1016/j.flora.2013.09.009

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Whinam J, Chilcott N, Bergstrom DM (2005) Subantarctic hitchhikers: expeditioners as vectors for the introduction of alien organisms. Biol Conserv 121: 207-219. doi:10.1016/j.biocon.2004.04.020

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

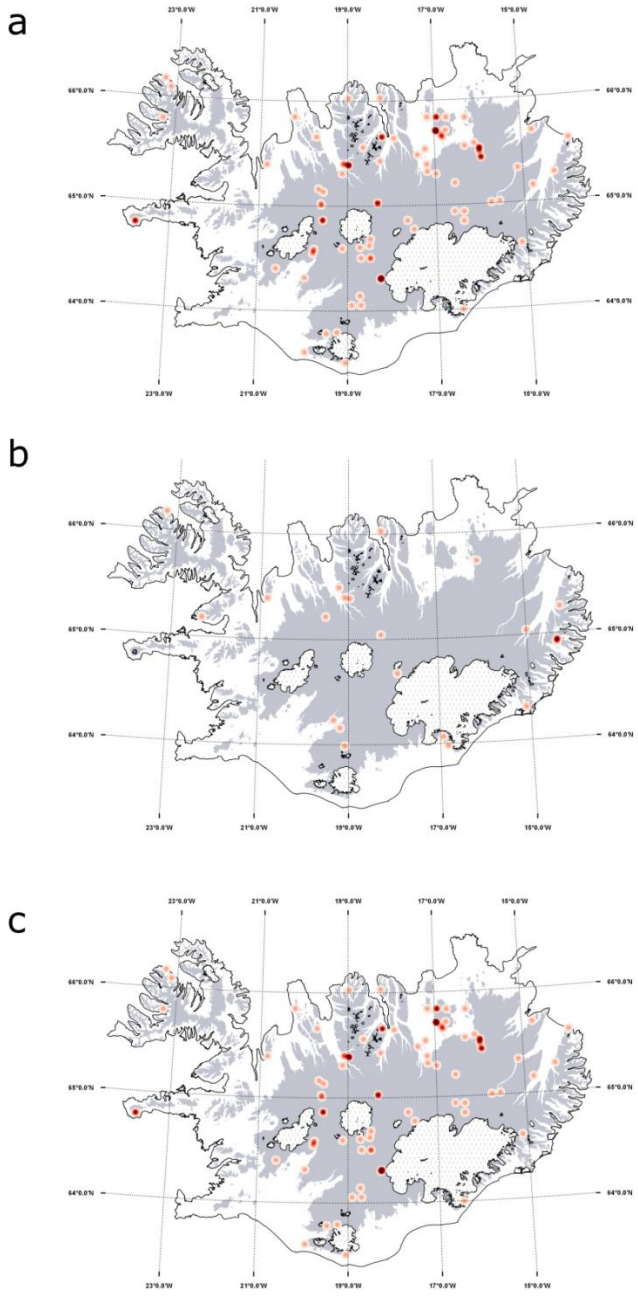

Fig. 1 Heat map showing the clusters of observations of non-native vascular plant species in highland and mountain areas in Iceland. a - all species, b - casual species, c - naturalised species

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

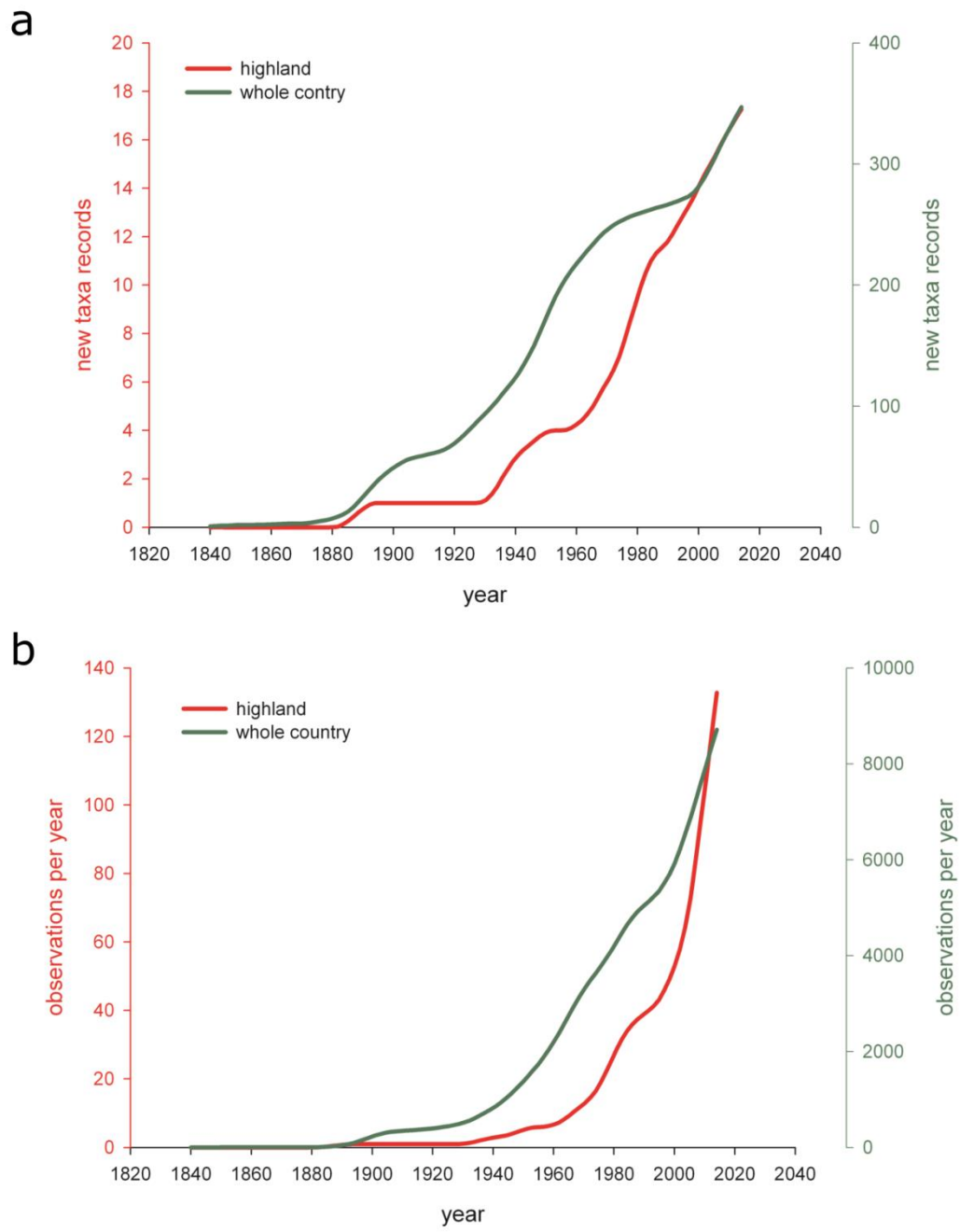

Fig. 2 LOESS curves showing dynamics and temporal trends in non-native flora of highland and mountain areas of Iceland (1840-2014) - LOESS curves. a - number of species, b - number of observations. Cumulative numbers were calculated on the basis of *per annum* new taxa records/observations

PeerJ PrePrints

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015

Table 1. Checklist of non-native vascular plants in highland and mountain areas of Iceland.

	Species	First record[a]	Last record[b]	Naturalisation status[c]	Life form[d]	Origin[e]	N[f]
1	*Alnus viridis* (Chaix) DC. ssp. *sinuata* (Regel) Á.Löve & D.Löve	2005	2005	CAS (NAT)	N	NAm, Asi	2
2	*Alopecurus pratensis* L.	1963	2011	**NAT** (NAT)	H	Eu, Asi	15
3	*Avenula pubescens* (Hudson) Dumort.	1978	1978	CAS (NAT)	H	Eu, Asi	1
4	*Claytonia sibirica* L.	2004	2004	CAS (CAS)	H	Asi, NAm	1
5	*Deschampsia cespitosa* (L.) Beauv. ssp. *beringensis* (Hultén) W.E. Lawr.	1996	2012	**NAT** (NAT)	H	NAm, Asi	24
6	*Lamium amplexicaule* L.	1988	1988	CAS (NAT)	T	Eu	1
7	*Lappula squarrosa* (Retz.) Dumort.	1888	1888	CAS (CAS)	H	Eu, Asi	1
8	*Lepidotheca suaveolens* (Pursh) Nutt.	1969	1999	CAS (NAT)	T	Eu, NAm, Asi	3
9	*Lolium perenne* L.	1981	1981	CAS (CAS)	H	Eu, Asi	1
10	*Lupinus nootkatensis* Donn ex Sims	1980	2014	**INV** (INV)	H	NAm	44
11	*Myosotis scorpioides* L.	1978	1980	CAS (NAT)	H	Eu, Asi	2
12	*Phleum pratense* L.	1935	2010	**NAT** (NAT)	H	Eu	22
13	*Rheum rhabarbarum* L.	1996	1996	CAS (CAS)	G	cult	1
14	*Salix alaxensis* (Andersson) Coville	2011	2011	**NAT** (NAT)	P	NAm	1
15	*Sinapis arvensis* L.	1937	1937	CAS (CAS)	T	Eu	1
16	*Stellaria graminea* L.	1946	2000	CAS(NAT)	H	Eu	7

PeerJ PrePrints

a) year of the first record is usually taken from databased herbarium collections. In some cases, however, they are based on observations only. This usually refers to taxa that are not present in herbaria collection in Iceland but were listed on the basis of literature reports

b) the data on most recent record are based on both herbarium and observation data

c) established after Pysek et al. (2004): CAS - casual alien species, NAT - naturalised alien species, INV - Invasive alien species. Naturalisation status in the country was given in brackets accoring to Wasowicz et al. (2013).

d) assigned according to Raukiær (1934) classification: G - geophyte, H - hemicryptophyte T - therophyte N - nano-phanerophytes P - phanerophytes.

e) geographic origin of the species: Eu - Europe, Asi - Asia, NAm - North America, cult - cultivated taxon.

f) total number of examined records

PeerJ PrePrints | https://dx.doi.org/10.7287/peerj.preprints.1165v2 | CC-BY 4.0 Open Access | rec: 22 Jun 2015, publ: 22 Jun 2015